



Breaking the Barrier Between System and  
Component Modeling: Coupling RELAP5-  
3D<sup>©</sup> & FLUENT

Relevant Applications

by

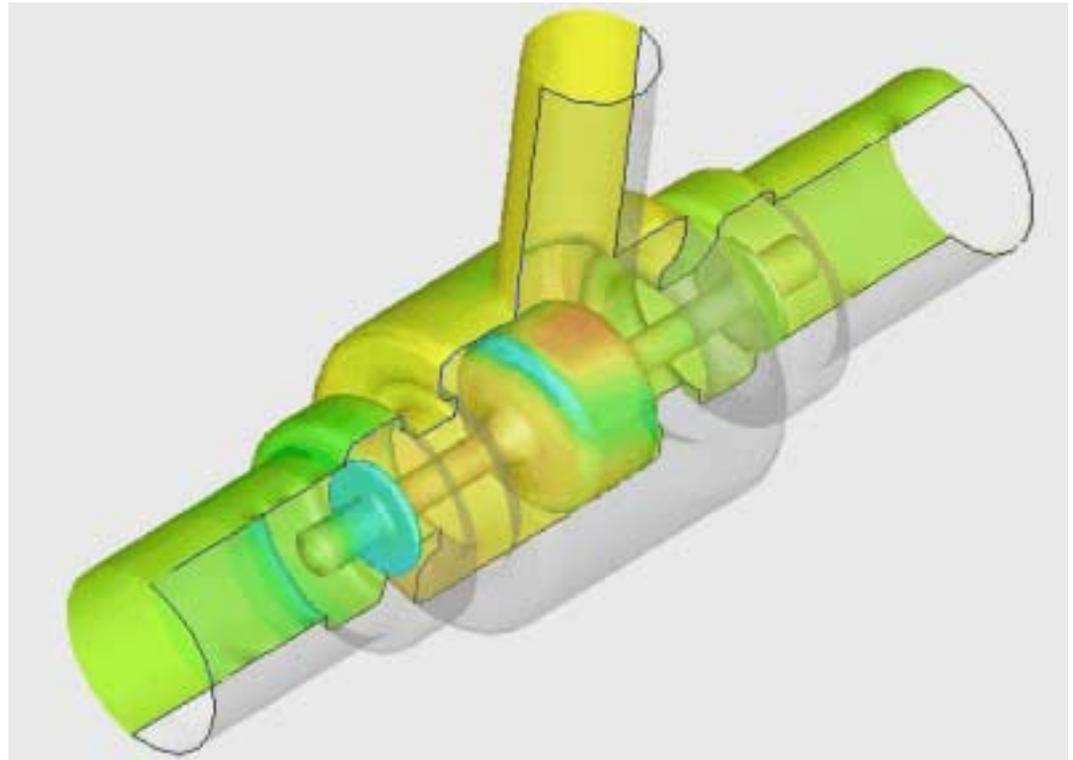
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Technical Support Engineer

Fluent Inc.  
[www.fluent.com](http://www.fluent.com)

# Outline

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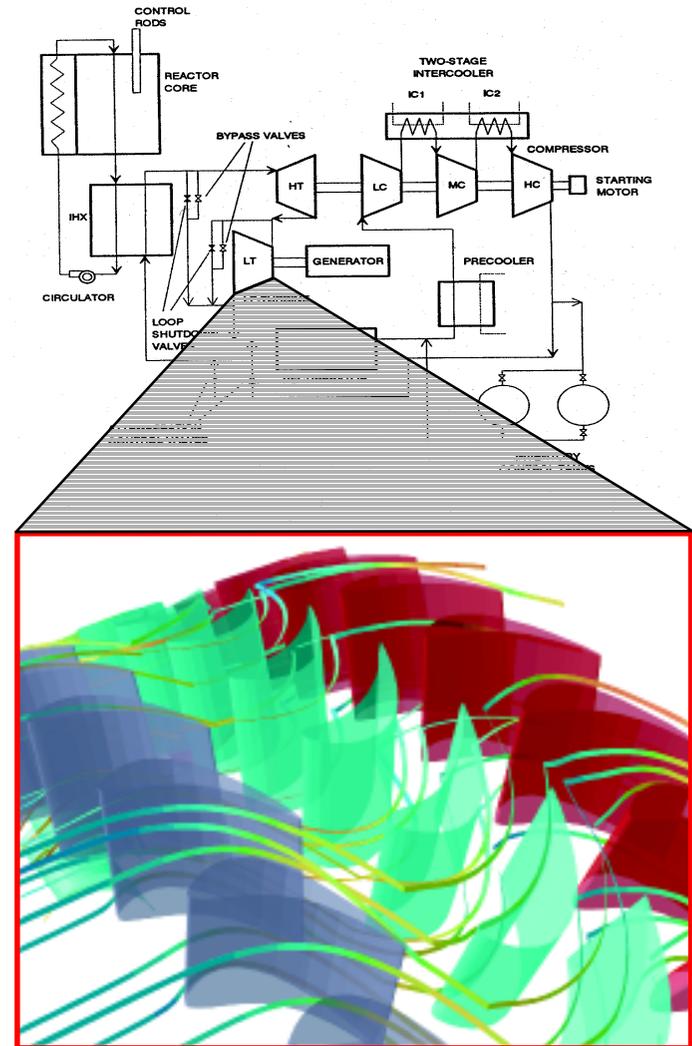
- ◆ FLUENT & RELAP5-3D<sup>®</sup> Coupling
- ◆ Introduction to Fluent Inc.
- ◆ What is CFD?
- ◆ Case Studies
- ◆ FLUENT Capabilities
- ◆ Summary



Contours of Pressure

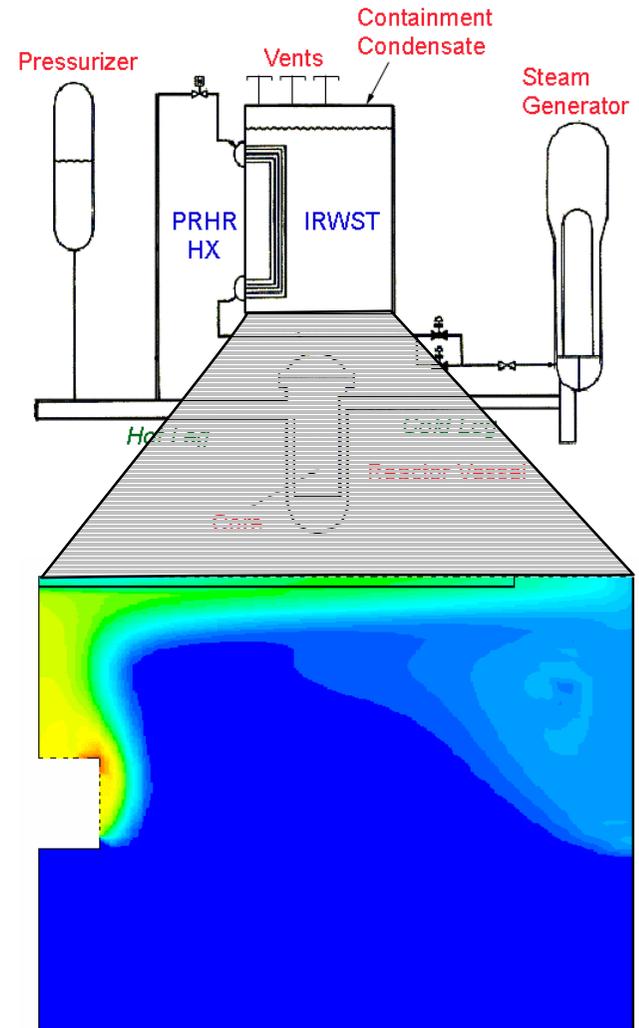
# Need for *Fluent* & *RELAP5-3D*<sup>©</sup> Coupling

- ◆ Enable an entire system to be modeled using 1 dimensional features of *RELAP5-3D*<sup>©</sup>
- ◆ Model some components of the system in detail using the 3 dimensional features of *FLUENT*



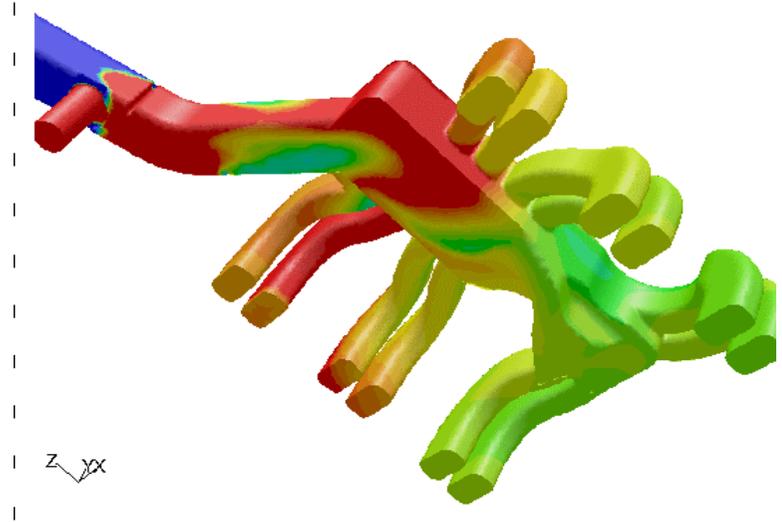
# Benefits of Fluent & RELAP5-3D<sup>®</sup> Coupling

- ◆ The performance of the system depends on the flow through each component, and vice versa
- ◆ Boundary condition information is transferred back and forth between the two codes
- ◆ Both the system and component behavior is more accurately predicted



# Fluent Coupling

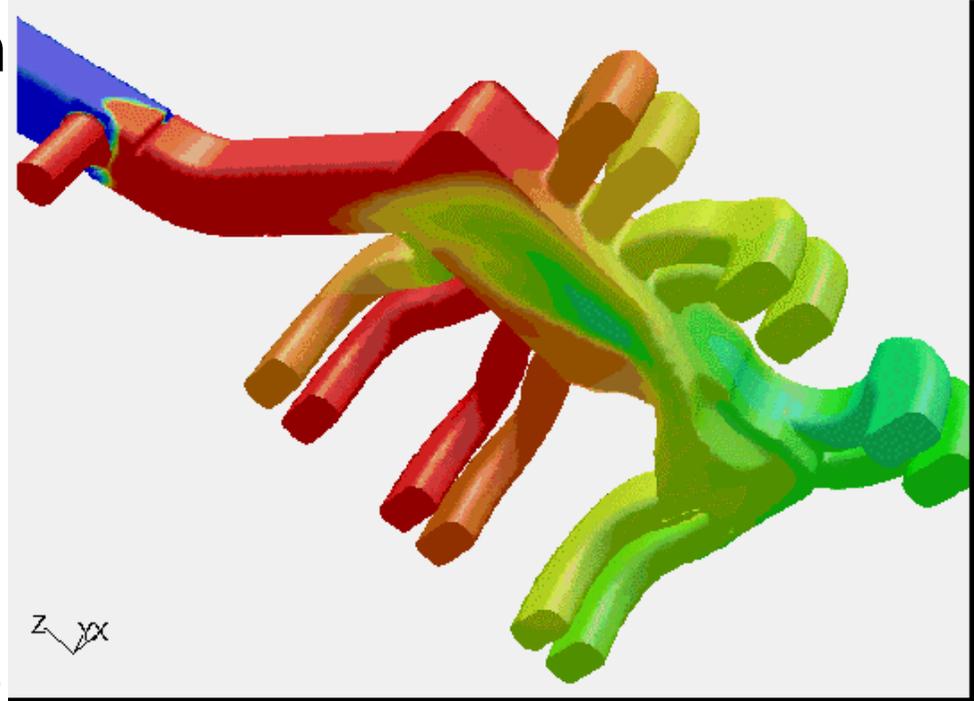
- ◆ A 1-D model of the powertrain system is constructed
- ◆ The intake manifold is represented as a “CFD component”



**Contours of Exhaust Gas Recirculation 18.9 ms into the cycle**

# Fluent Coupling

- ◆ The coupled solution shows the transient flow in the manifold due to continuously updated boundary conditions
- ◆ The system performance is more accurately predicted as well



**Contours of Exhaust Gas  
Recirculation**

# ***Introduction to Fluent Inc.***

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- ◆ Fluent Inc. develops and markets fluid dynamics software for the analysis of engineering processes
- ◆ Software can be used for studying:
  - Fluid flow and heat transfer
  - Complex reactions, materials, processes
- ◆ Largest CFD vendor in the world

# Fluent Worldwide

## Europe

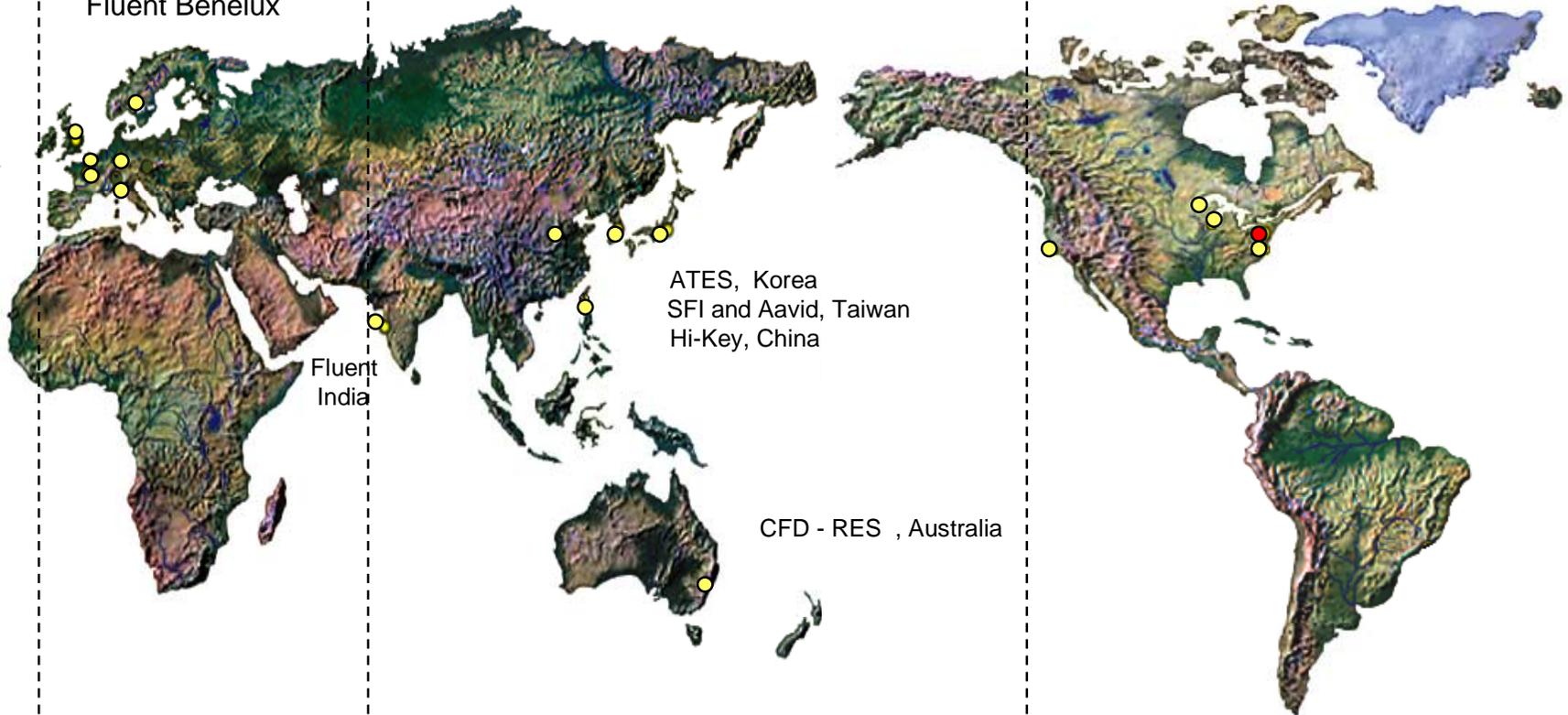
Fluent UK  
Fluent France  
Fluent Germany  
Fluent Italy  
Fluent Sweden  
Fluent Benelux

## Asia/Pacific

Fluent Asia-Pacific, Japan  
Tokyo and Osaka  
Fluent India

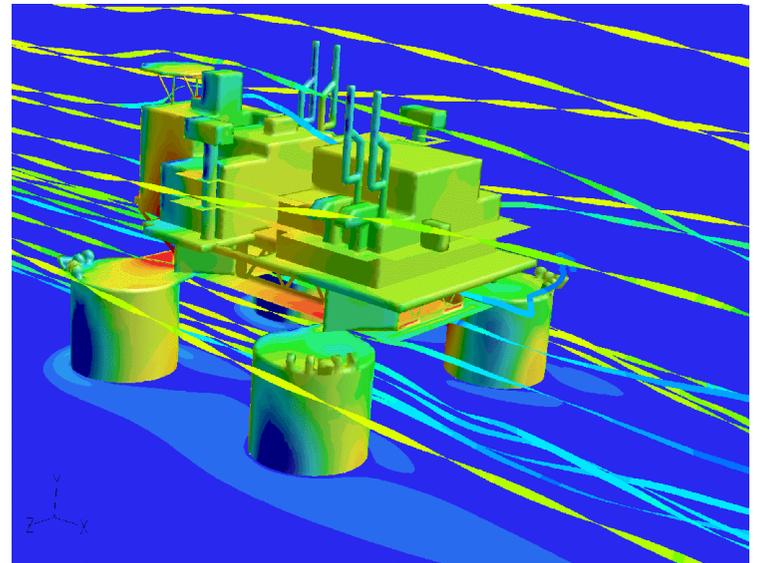
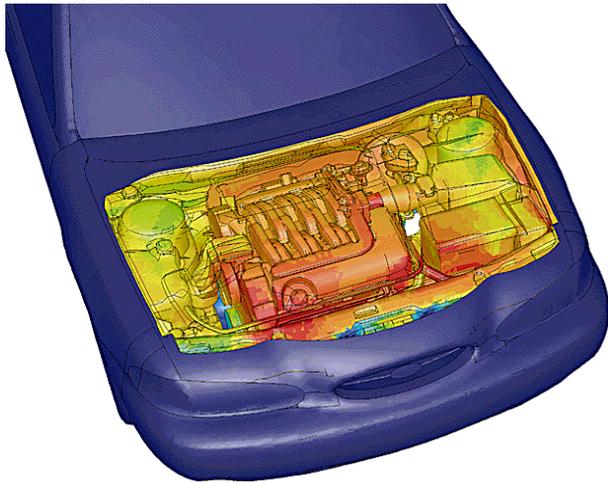
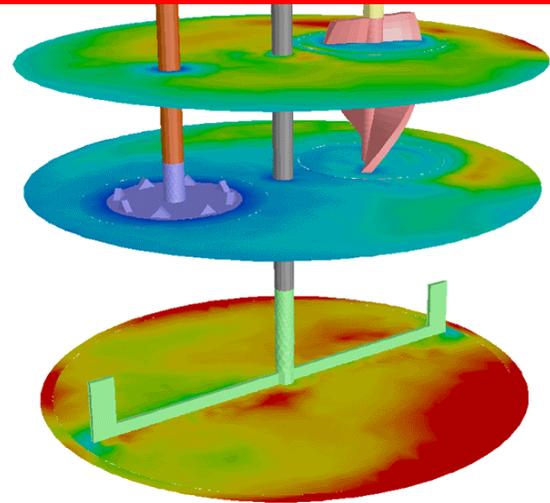
## N. America

**Fluent Inc. HQ - Lebanon, NH**  
Evanston, IL  
Santa Clara, CA  
An Arbor, MI  
Morgantown, WV



# Major Markets Served

- Aerospace
- Turbomachinery
- Power Generation/Nuclear
- Chemicals/Petrochemical
- Automotive
- Computers/Semiconductors
- Materials/Metallurgy
- HVAC

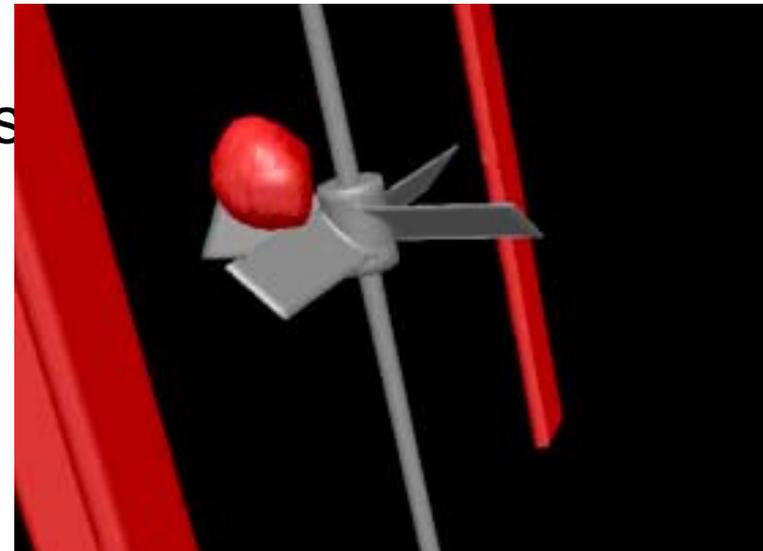
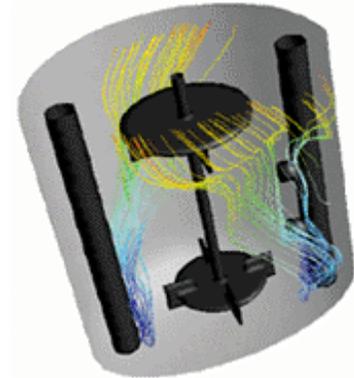


# Computational Fluid Dynamics

- ◆ Fluid flow, heat and mass transfer, phase change, chemical reaction, mechanical movement, and deformation of related solid structures
- ◆ Navier Stokes Equations

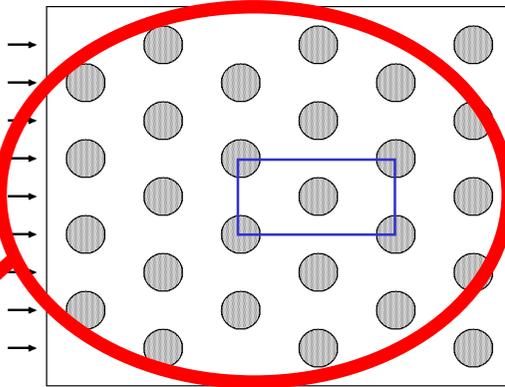
$$\frac{\partial(\rho\phi)}{\partial t} + \text{div}(\rho\phi\mathbf{u}) = \text{div}(\Gamma \text{grad}\phi) + S_\phi$$

- ◆ Numerical Solution Techniques
  - Finite Difference
  - Finite Elements
  - **Finite Volume**

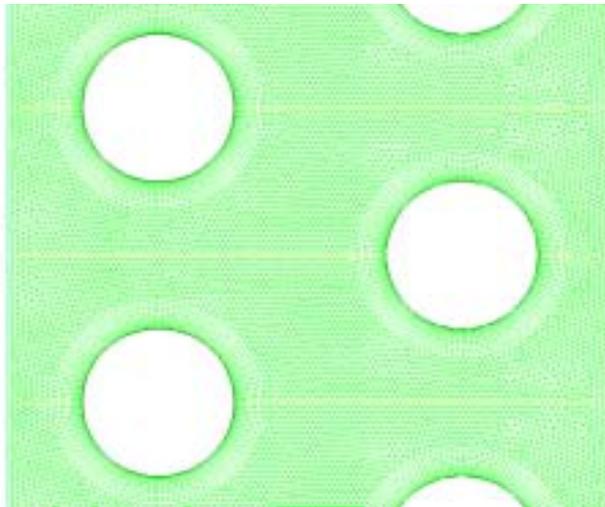


# How CFD Analysis Works

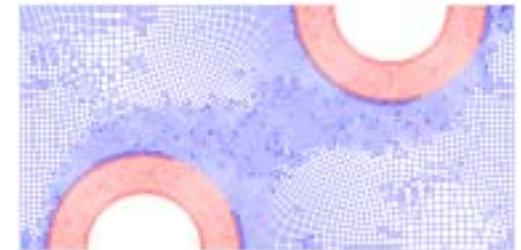
1. User defines the problem...



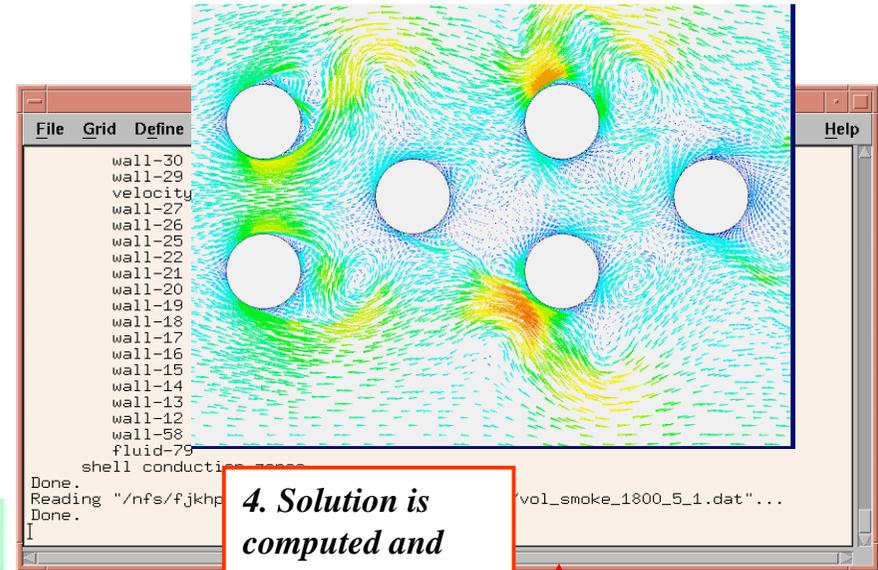
2. A mesh is constructed



3. Model is set up in Fluent



4. Solution is computed and viewed in Fluent!



# ***Case Studies***

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- ◆ Tube and Shell Heat Exchanger
- ◆ Steam Generator Flows
- ◆ Coolant Control Valve

# ***Heat Exchanger Performance Improvement***

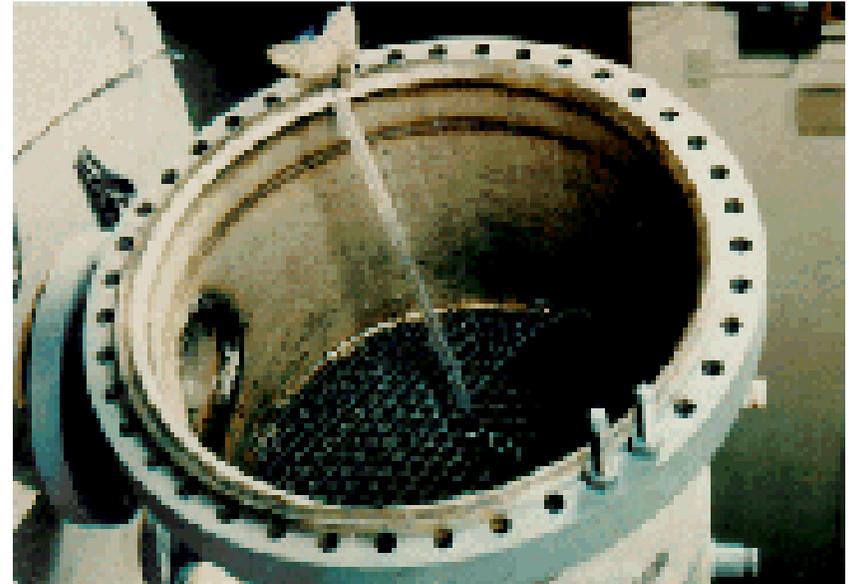
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## ◆ **Problem:**

- Under-performing 324 tube heat exchanger
- 700mm x 2500mm long vertical with 200mm nozzles on the tube side
- Tube side flow 90757kg/hr at 69.5 C

## ◆ **Solution:**

- Replace the device
- German Chemical company retains Cal Gavin Engineers to perform analysis

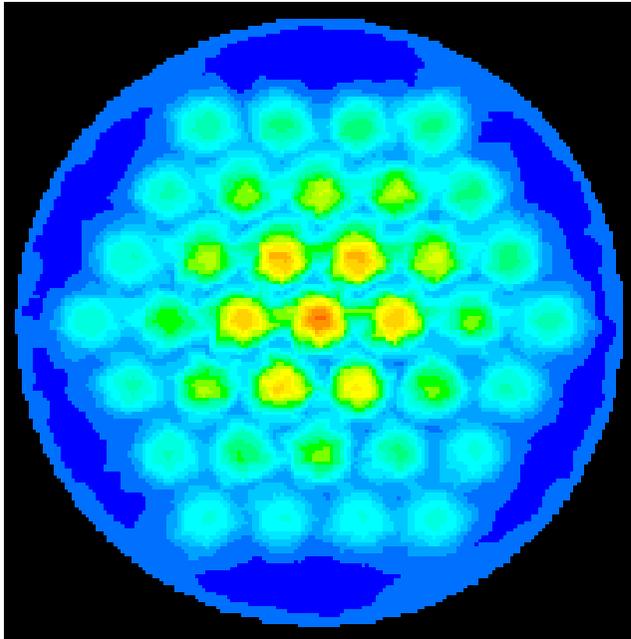


*Courtesy of Cal Gavin Ltd.*

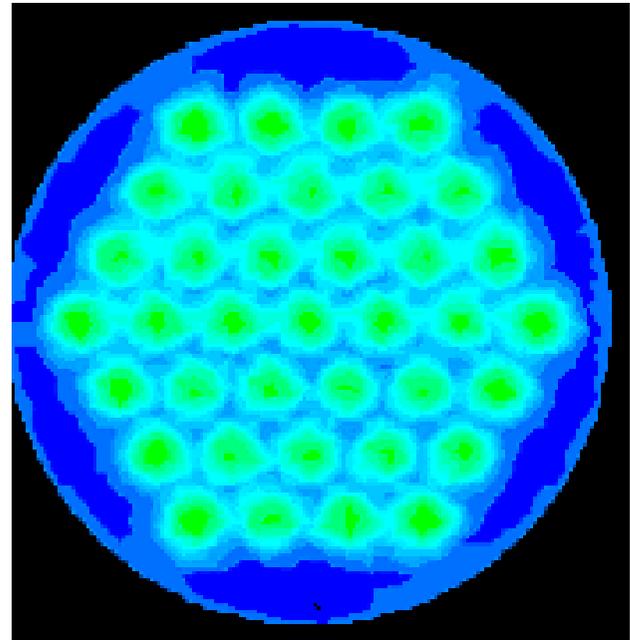
# ***Axial Velocities Across the Outlet***

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**Maldistributed**



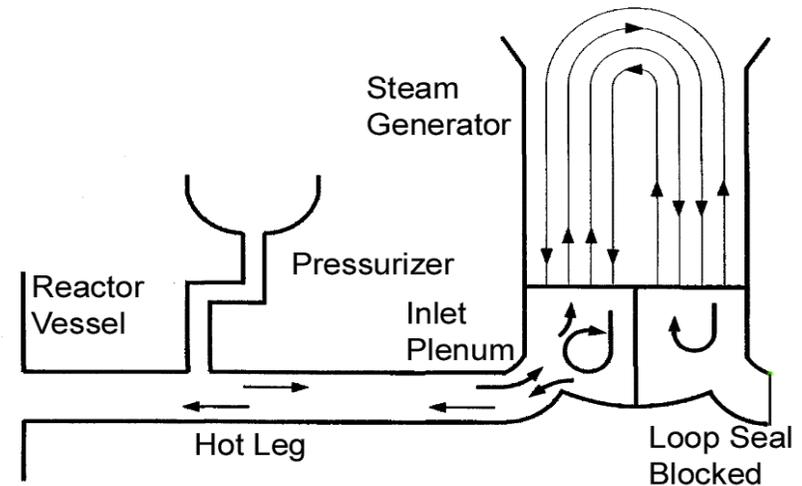
**Improved**



**Look for local hot spots and temperature uniformity**

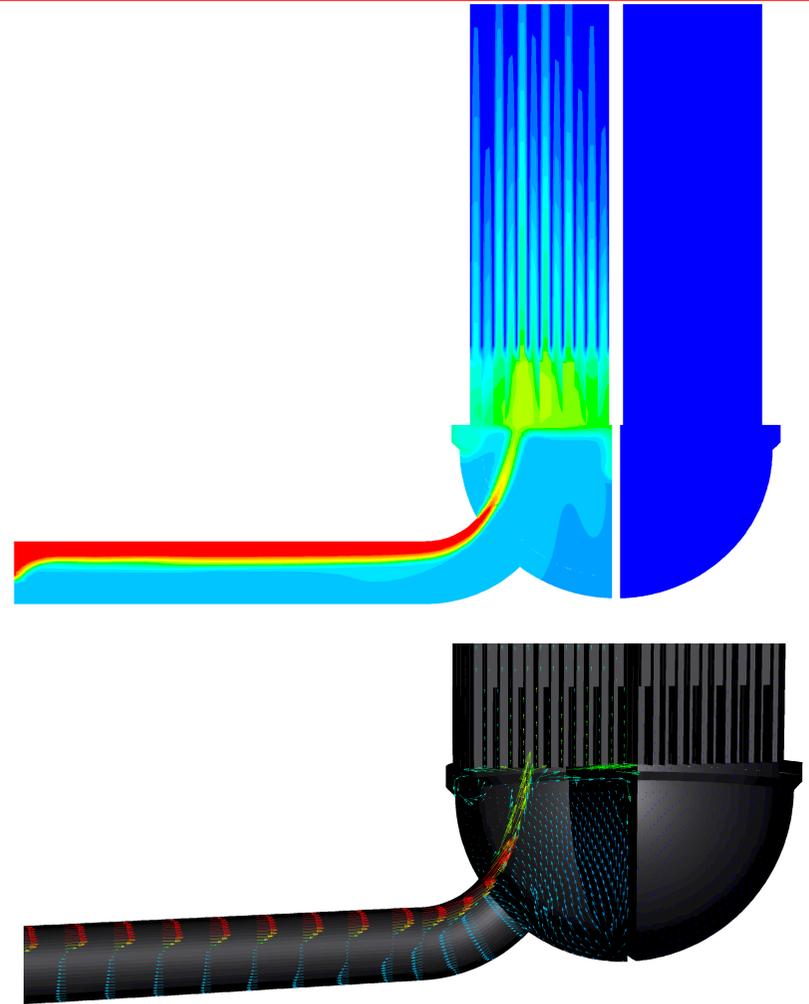
# Severe Accident Steam Generator Flows

- ◆ FLUENT is used to simulate the flow in a steam generator following a severe loss of coolant accident
- ◆ Due to blockage in the coolant loop and seals, cooling is impaired
- ◆ The simulation is used to determine the extent of the cooling failure – whether it is restricted to the coolant piping or extends into the steam generator tubing



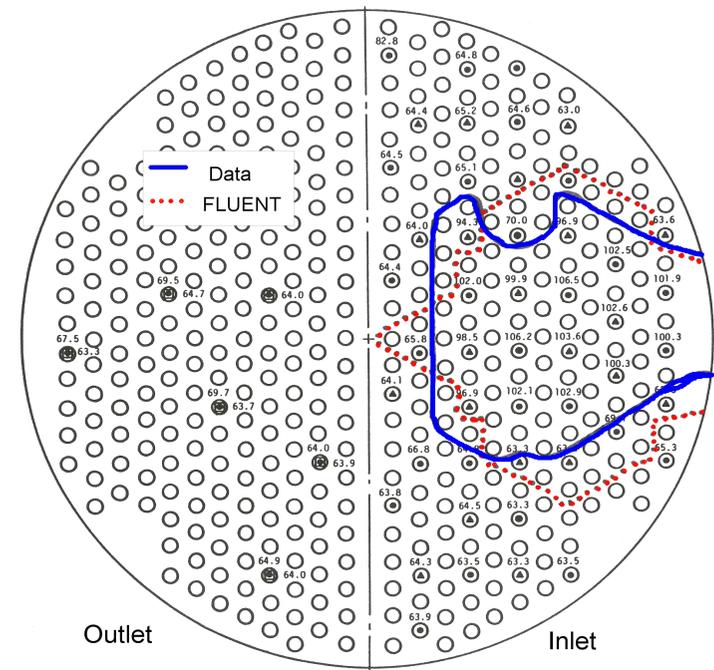
# Severe Accident Steam Generator Flows

- ◆ Temperature contours on the symmetry plane (top) show hot coolant on the top of the pipe
- ◆ Velocity vectors (bottom) show the directions of the hot and cool liquid flows
- ◆ The predicted average hot and cold temperatures are within 1.5 – 2K of the measured values



# Severe Accident Steam Generator Flows

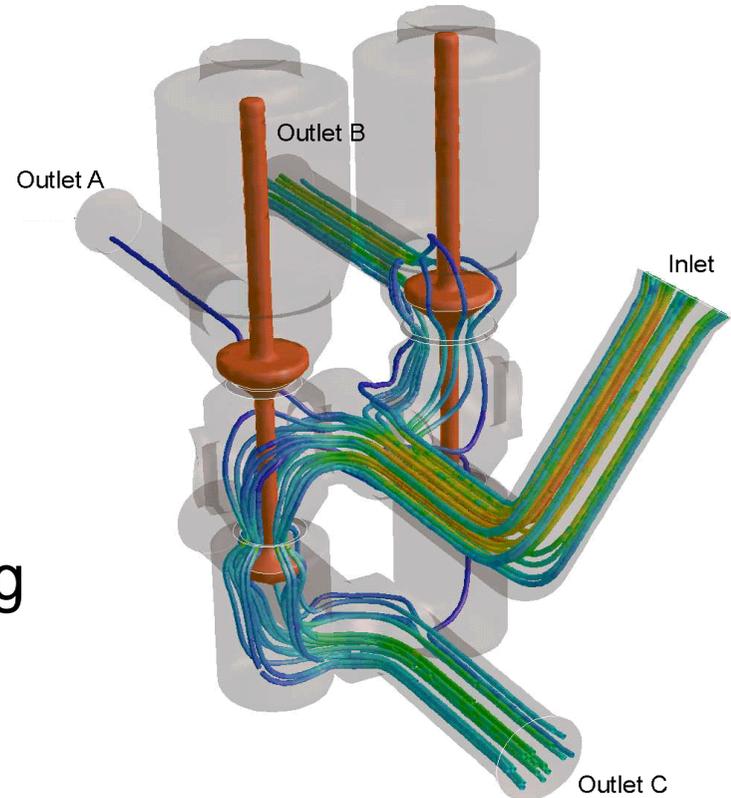
- ◆ Predictions of the number of tubes carrying hot flow are compared to data
- ◆ FLUENT overpredicts the region of hot flow by 16 tubes, or 7% of the total bundle
- ◆ Overall, the CFD results are in very good agreement with data and provide more information than a limited number of thermocouples can



*Courtesy of the US Nuclear Regulatory Commission*

# Coolant Control Valve

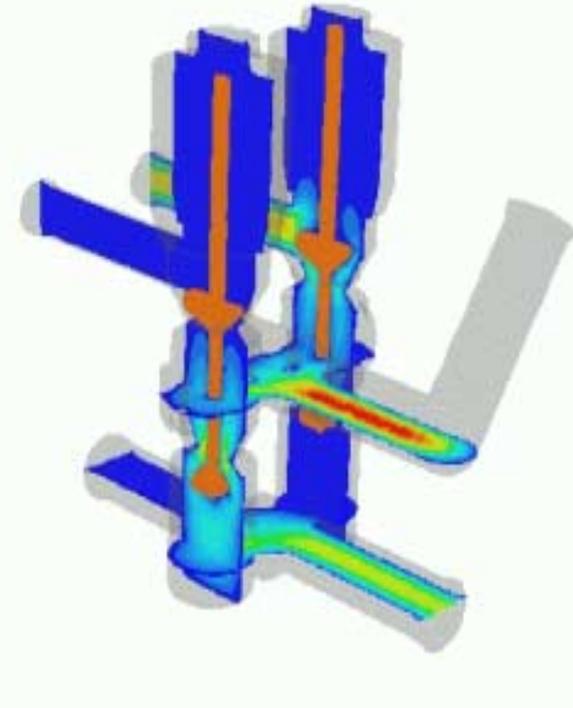
- ◆ Dual control valve is used for automotive HVAC coolant control
- ◆ Driver and passenger can control temperatures independently
- ◆ Valve motion is simulated using the moving mesh feature
- ◆ Time-varying profiles describe the motion of the valve spools



*Courtesy of Robert Bosch Corporation*

# Coolant Control Valve

- ◆ Deforming mesh capability has been demonstrated with the coolant control valve
- ◆ When compared to steady-state analyses, a deforming mesh analysis produces a more realistic representation of flow through components such as valves and pumps

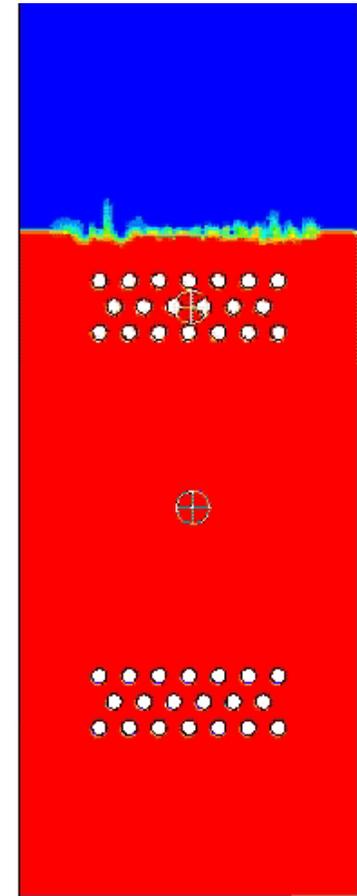
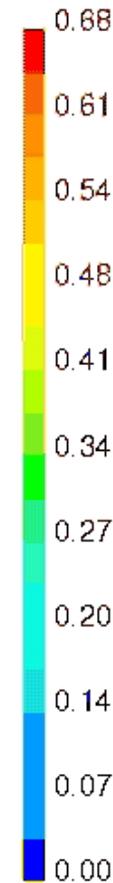


Contours of Velocity Magnitude (m/s) (Time=2.5000e-02)  
FLUENT 6.0 (3d, segregated, dynamic grid, lam, unsteady) Aug 28, 2001

Contours of Velocity Magnitude *Courtesy of Robert Bosch Corporation*

# Fluent Capabilities

- ◆ Model Building
- ◆ Physical Models
- ◆ Multiphase Models
- ◆ Dynamic Mesh Adaption
- ◆ Moving and Deforming Mesh
- ◆ Visualization



Contours of Solid Phase

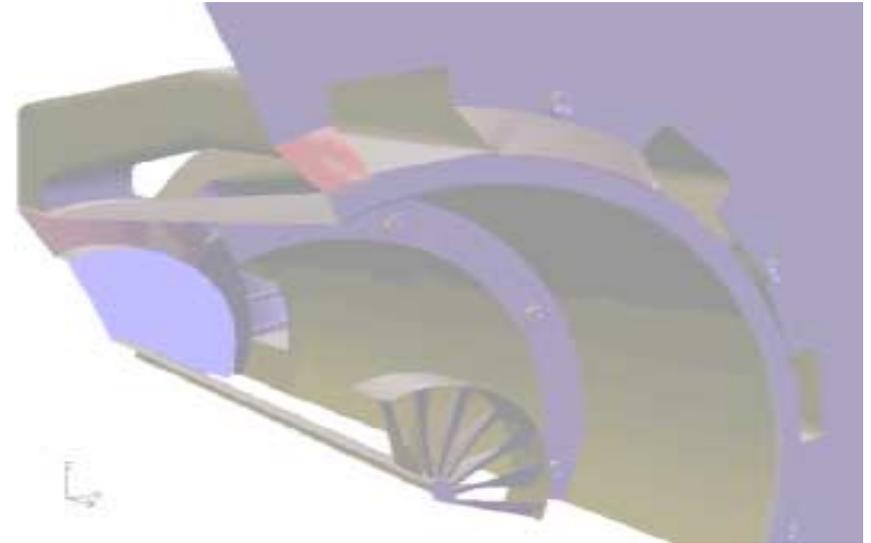
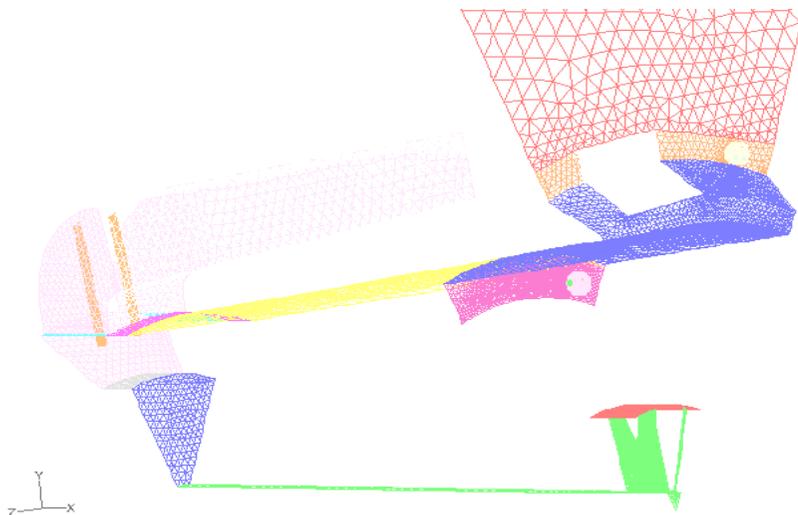
*Courtesy of BASF*

Contours of Volume fraction of second phase  
Nov 26, 2001  
IT 6.0 (2d, segregated, eulerian, lam, unsteady)

# Fluent Capabilities

## ◆ Model Building

- Fully integrated
- Solid geometry modeling



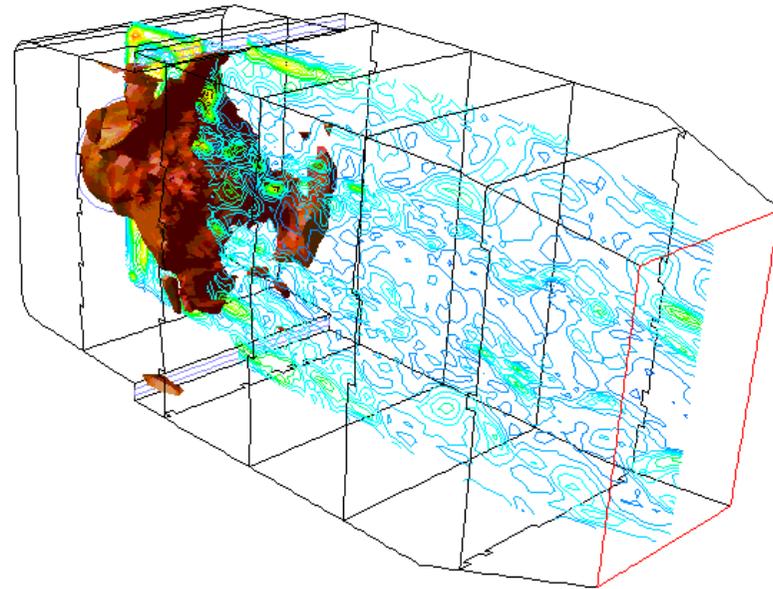
- Geometry and mesh import from CAD/CAE
- Meshing
- Mesh visualization and quality diagnostics

# ***Fluent Capabilities***

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## ◆ Physical Models

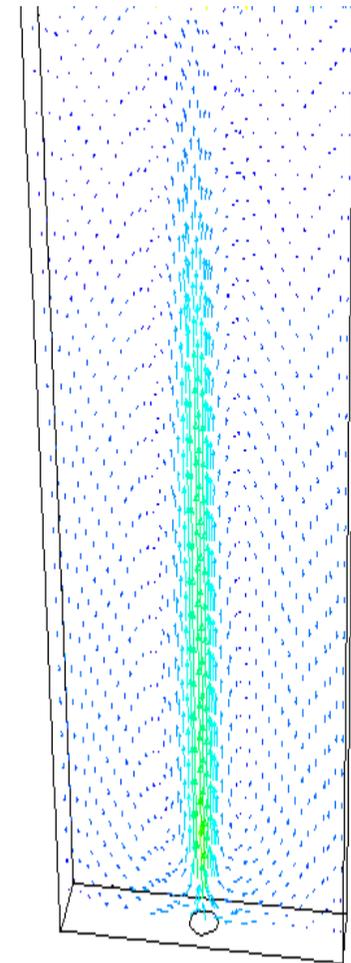
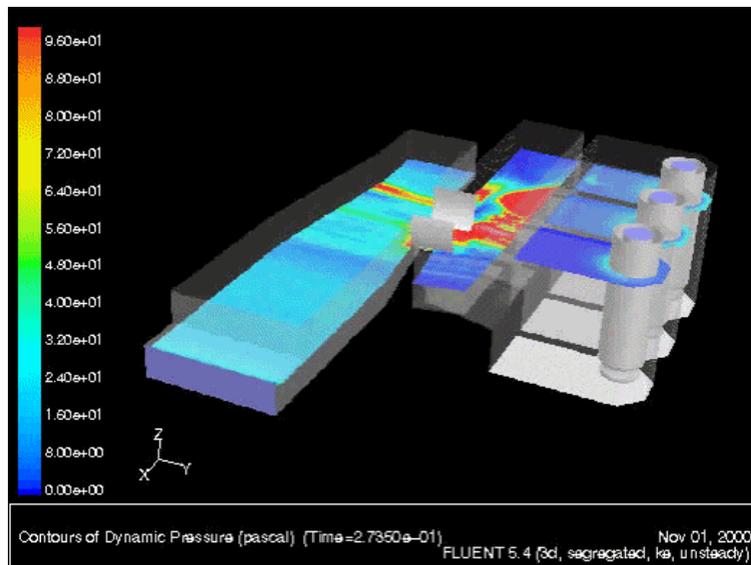
- Heat transfer, species transport and reacting flows
- Multiple reference frames, sliding mesh and mixing plane model
- Inviscid, laminar or turbulent



*Courtesy of General Electric*

# Fluent Capabilities

- ◆ Multiphase Modeling
  - Particle Tracking
  - Free Surface Flows
  - Mixture Model
  - Fluid-Fluid, Fluid-Solid

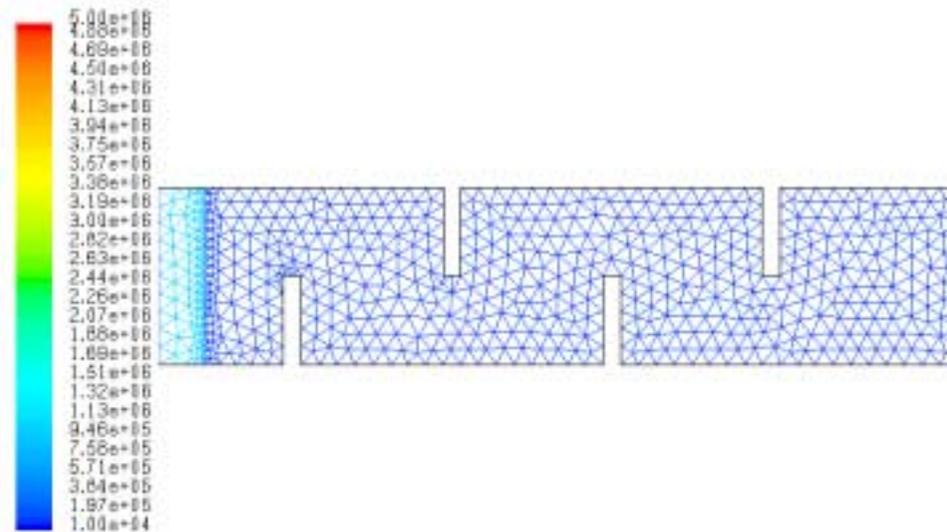


**Bubble Column**

# Fluent Capabilities

## ◆ Dynamic Mesh Adaption

- Improve accuracy
  - Refine the grid based on flow solution gradients or geometric details for higher resolution of flow details.
- Increase model efficiency
  - Add grid resolution only where it is needed



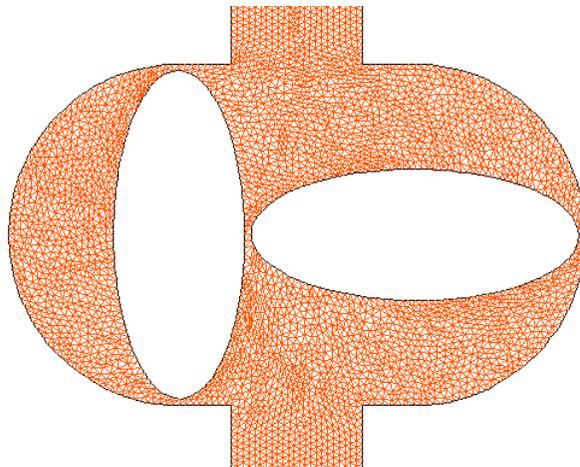
Contours of Static Pressure (pascal) (Time=0.0000e+00) May 07, 2002  
FLUENT 6.1 (2d, coupled exp. unsteady)

**Mesh Coloured by Contours of Static Pressure**

# Fluent Capabilities

## ◆ Moving and Deforming Mesh

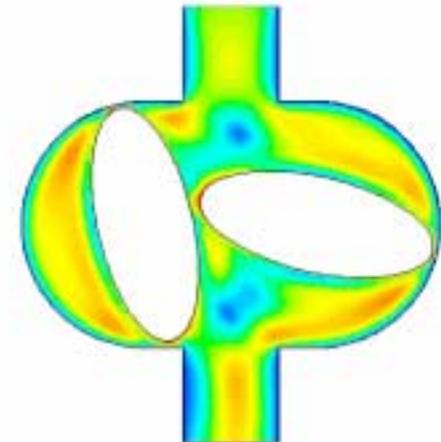
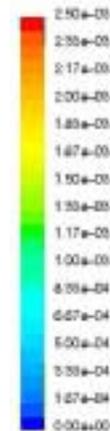
- The moving mesh uses three possible techniques:
  - moving nodes while preserving connectivity, localized re-meshing, dynamic layering
- The result is a high quality mesh at all times during the calculation



Grid (Time=2.0500e+02)

Mar 21, 2002  
FLUENT 6.0 (2d, segregated, dynamic grid, lam, unsteady)

**Mesh Deformation**



Contours of Velocity Magnitude (m/s) (Time=2.7000e+02)

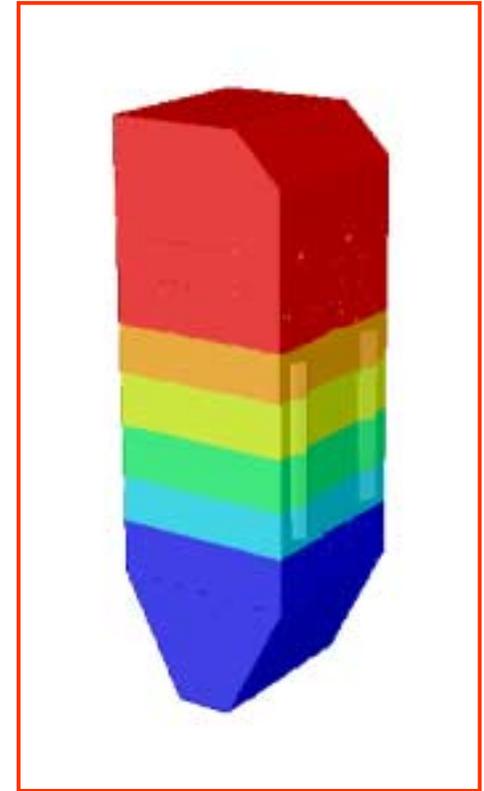
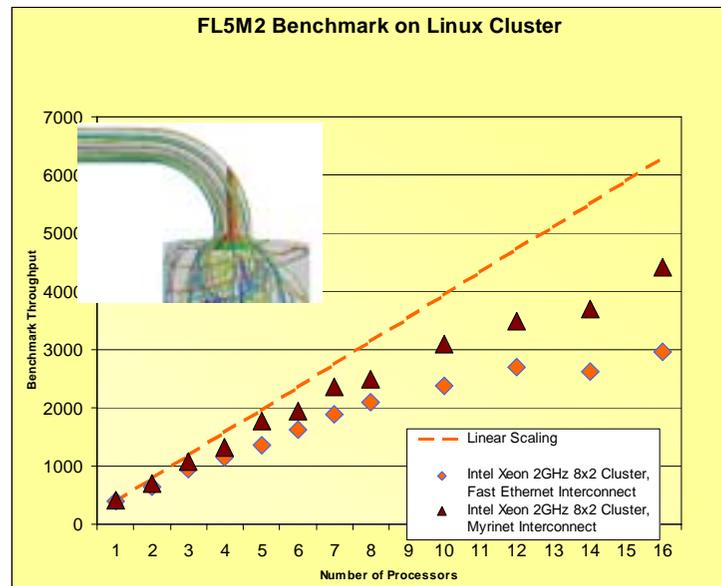
Apr 16, 2002  
FLUENT 6.0 (2d, segregated, dynamic grid, lam, unsteady)

**Velocity Magnitude Contours**

# Fluent Capabilities

## ◆ Parallel Computing

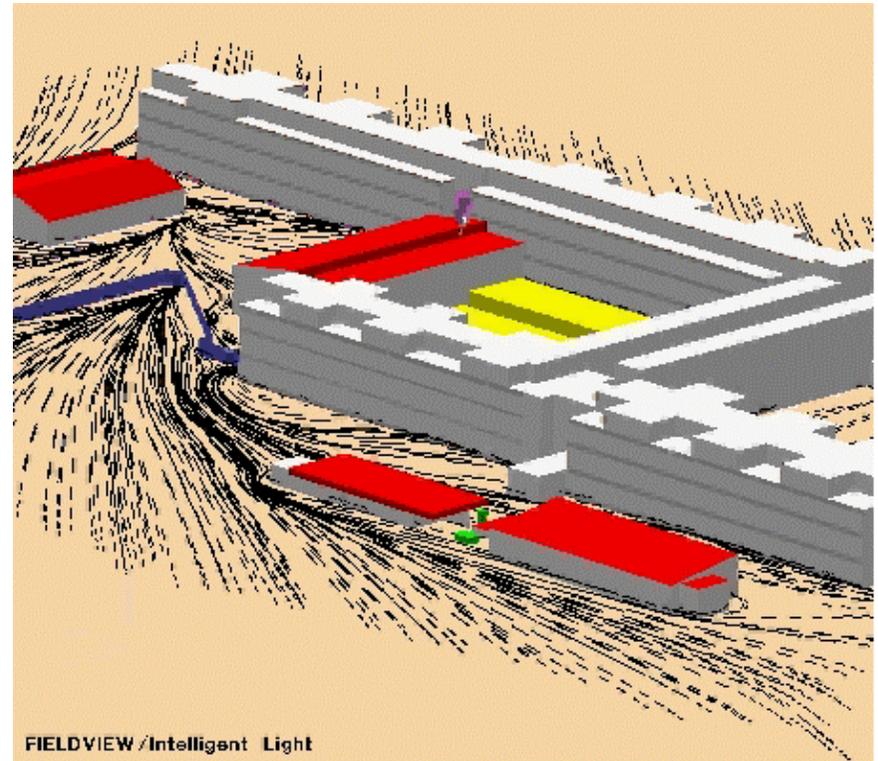
- Parallelization available on networks of workstations or multiple processor workstations
- Partitioning done automatically



Grid partitions on a utility boiler

# Fluent Capabilities

- ◆ Visualization
  - 3D visualization tools
  - Animation
  - Quantitative reports
  - Integrals and averages
  - Customized reports

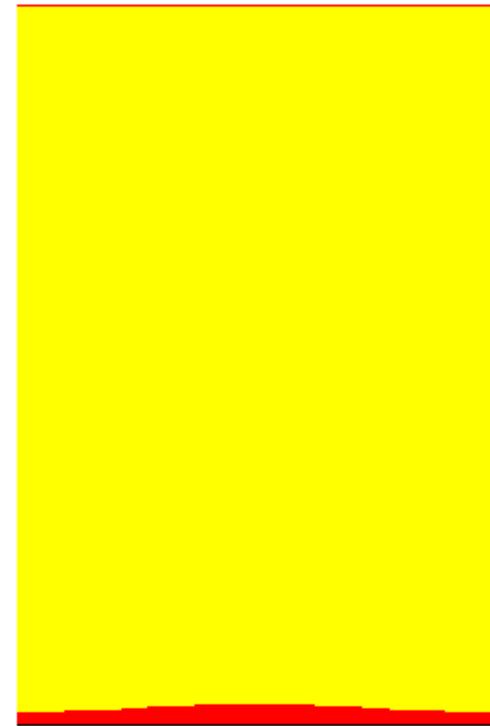


**Plume Dispersion**

# Summary

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- ◆ A number of industrial applications have been identified which may benefit from the coupling of FLUENT & RELAP5-3D<sup>©</sup>.
- ◆ Overall predictions of the system and component performance are expected to be more accurate



Volume fraction of vapor  
during film boiling